

COMPUTATIONAL ANALYSIS OF GAS PHASE MIXING IN A CO FIRED BURNER, USING DIFFERENT GEOMETRIES

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ABSTRACT

The study of swirling jet combustor for biomass coal co-firing is of great interest for energy industry; the biomass co firing can serve as a NOx reduction method as well as the better use of renewable energy source. Large eddy and RANS model simulation has been performed. Usually pulverised coal-biomass mixture enters the furnace along with primary air through primary pipe; the secondary pipe provides necessary air and mixing for combustion. The improved model has three passages including primary, secondary and middle one for swirling. The simulations on two geometries have been compared; the aim is to design a better and improved burner model for better pre combustion mixing in the biomass co fired furnace. The single phase k- ϵ and LES simulation have been performed on both geometrical models. The results from two ways and three way geometry have been compared with each other as well as with the results from the furnace model used by Apte and Mahesh

KEYWORDS: Swirling Jet, Co-firing, Biomass

INTRODUCTION

During combustion process the fossil fuels release carbon dioxide, carbon monoxide, SOx and NOx. Coal has different types and its chemical and physical properties of coal change with varying amount of carbon [1].

Biomass is one of the main renewable energy sources having reasonable cost compared with other renewable sources. Biomass may be forestry material, agriculture waste, straw, municipal waste, sewage sludge etc [3]. The biomass utilisation can contribute in reducing NOx, SOx, CO_2 and CO. The biomass material has more volatility but low energy than hard coal; a biomass- coal blend contains balanced volatility and energy. Usually biomass coal co fired or retrofitted burners consist of primary air pipe conveying air fuel mixture, secondary air (swirled) pipe conveying additional air for turbulence and mixing [4]. The modified geometrical model consists of primary air pipe secondary pipe and tertiary flow pipe. The air from secondary air helps to increase the turbulence mixing and produces wakes in the region away from the centreline. The results from two ways and three way geometry have been compared with each other as well as with the results from the furnace model used by Apte and Mahesh [8] which is two way model geometry. Different models and schemes have been used, and found three way assembly better than two way assembly for pre combustion mixing and better combustion will result in reduction of emissions, the geometrical models have been shown in the figure below

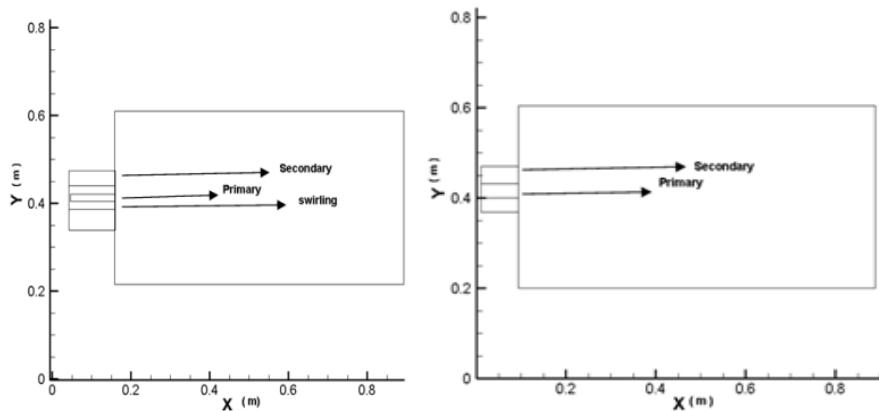


Figure 1: Schematic of Biomass Co Fired (a) Three Way Assembly Furnace Model (b) Two Way Assembly Furnace Model (c) Geometry and Mesh Used by Apte and Mahesh [8]

TURBULENCE MODELLING

Turbulent flow can be computed by using sub grid scale or RANS model; turbulence rate is proportional to mean strain rate [4]. The mathematical models are used to investigate the turbulence effects in the flow; it has been proved by research that turbulence modelling is totally related with transport equation and species [2]. The turbulent flow may be decomposed into velocity and pressure components.

LES is better tool for jet shear and wall jet impingement [7], LES results can more easily be compared with experimental and published work for validation. The LES solves the filtered Navies Stokes equation and gives the better results than RANS viscous models here also the LES simulations have been performed and compared with the RANS models. Following are the flow parameters here for three way assembly design

Table 1

Primary (m/sec)	Secondary(m/sec)	Tertiary (m/sec)	Temperature	Pressure (Pa)
15	10	18	Not considered	atmospheric

For two way assembly geometry, there is not Tertiary the secondary is swirling flow temperature remains constant that's why the energy equation has not been considered here.

METHODOLOGY

The k-epsilon and LES simulation has been performed over the simple geometrical model of co fired furnace first, and then the simulation for improved assembly (same assembly with additional pipe) was done. 2nd order upwind scheme for flow and quick scheme for turbulence was selected with simple algorithm. The simulation results got from each assembly. Simulation results were compared with each other and also with the simulation results from Apte and Mahesh [8].

RESULTS AND DISCUSSIONS

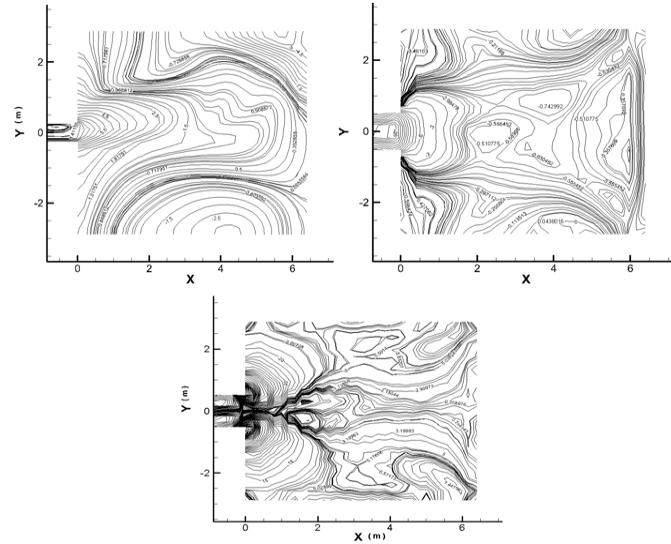


Figure 2: Axial Velocity Contours for (a) Reference Geometry Apte and Mahesh [8] (b) Three Way Geometry
(c) Mean Y-velocity for Three Way Geometry (d) Mean X-velocity for Three Way Geometry

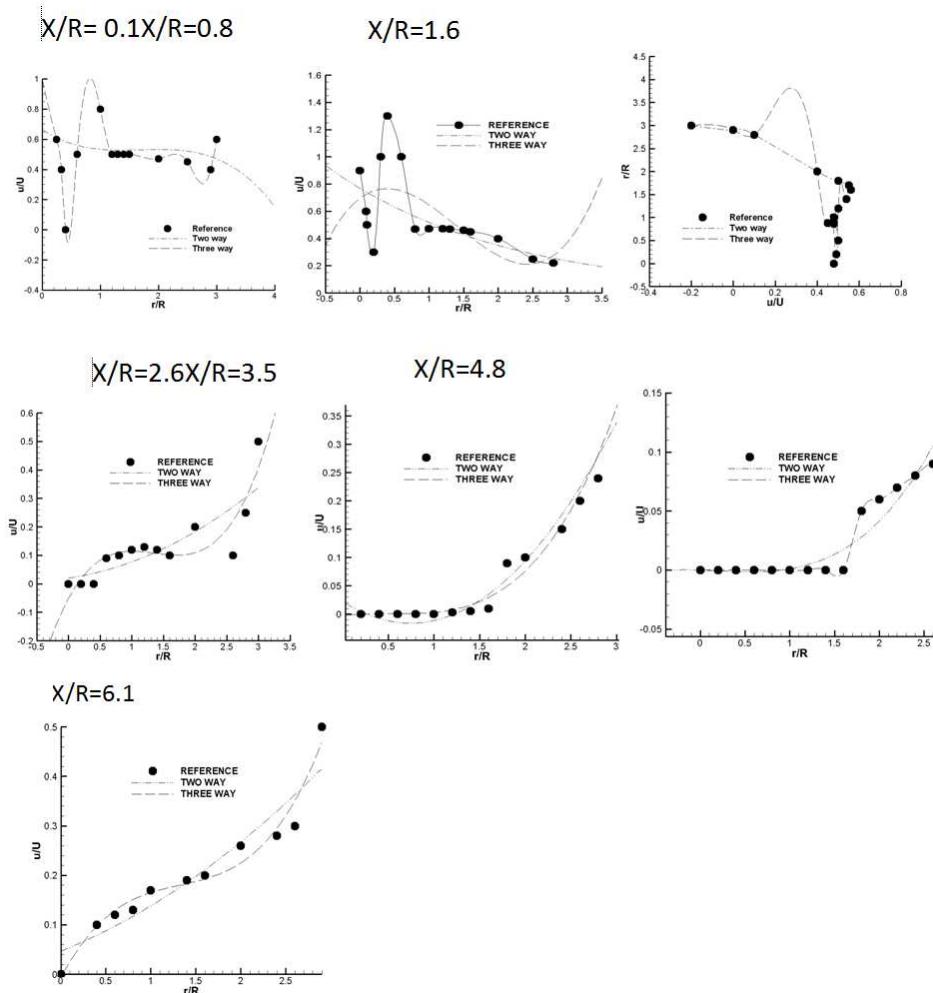


Figure 3: Axial Velocity Comparison between LES on Two Ways (---) Three Way (----) and Experimental (●, Somerfield and Qiu, 1991) for Swirling Flow in a Co Fired Combustor

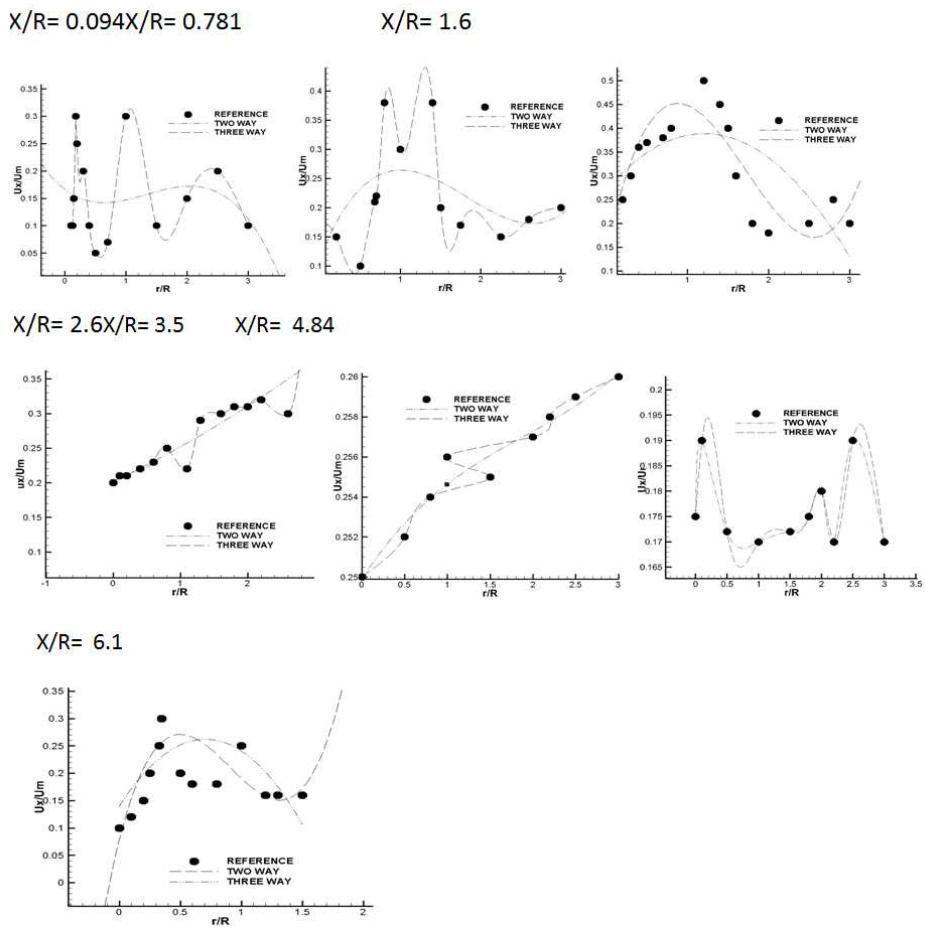


Figure 4: Rms of Axial Velocity Comparison between LES on Two Ways (---) Three Way (----) and Experimental (●, Somerfield and Qiu, 1991) for Swirling Flow in a Co Fired Combustor

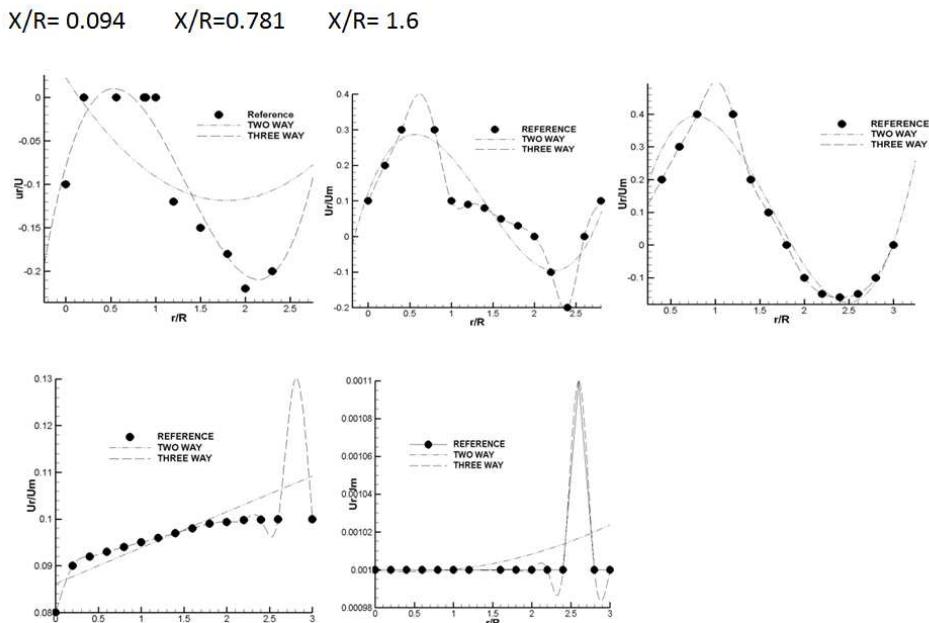


Figure 5: Radial Velocity Comparison between LES on Two Way (---) Three Way (----) and Experimental (●, Somerfield and Qiu, 1991) for Swirling Flow in a Co Fired Combustor

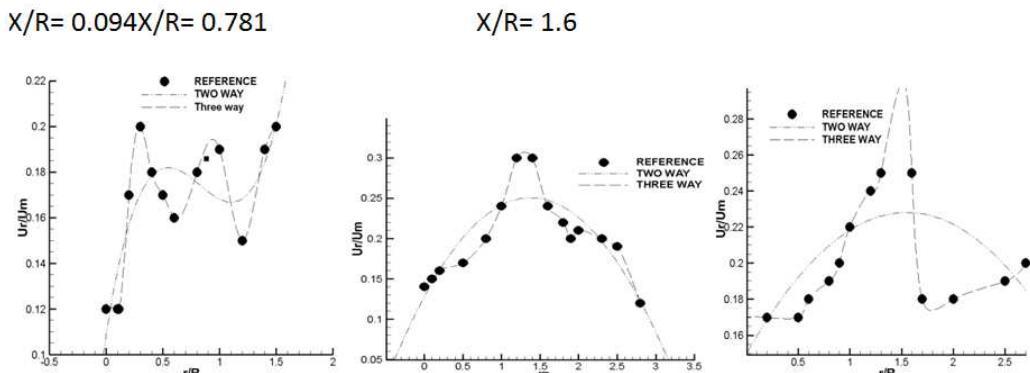


Figure 6: Rms of Radial Velocity Comparison between LES on Two Ways (●) three way (---) and Experimental, (Somerfield and Qiu, 1991) for Swirling Flow in a Co Fired Combustor

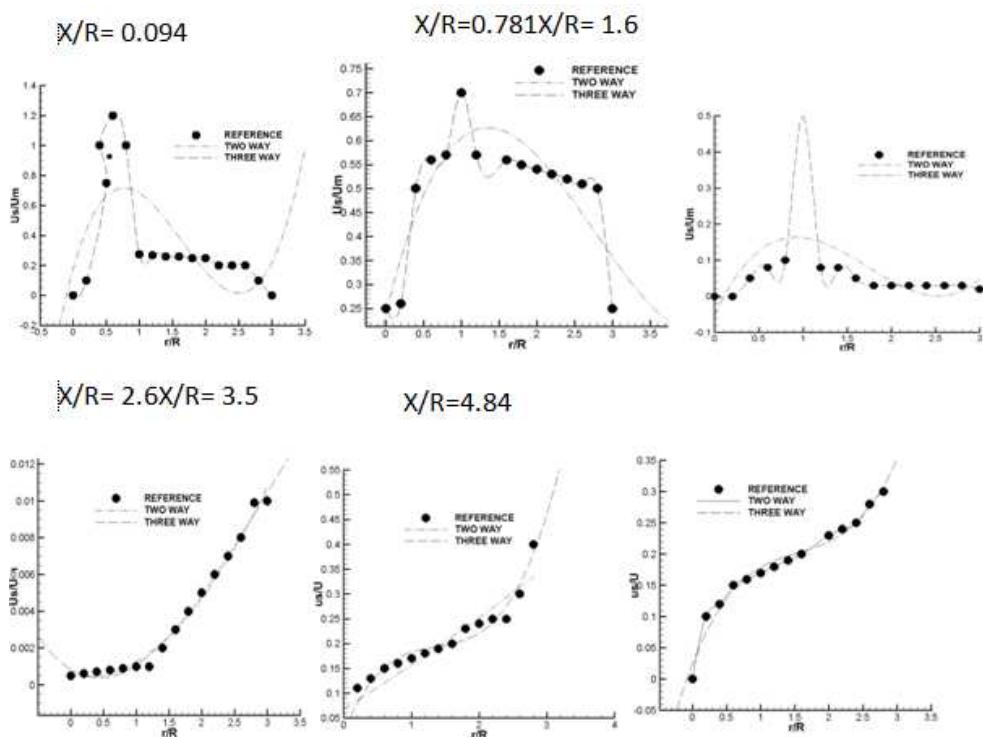


Figure 7: Swirl Velocity between LES on Two Way (—) Three Way (---) Experimental (●, Somerfield and Qiu, 1991) for Swirling Flow in a Co Fired Combustor

The improved burner model design has better efficiency than a simple co fired burner; the main reason is the addition of annular pipe. The effect of a jet velocity ratio shows the complexity of isothermal models [4]. Simulation was run over two assemblies (new and old assembly) and reference geometry. It can be seen in figure 3 that the flow in new geometry has better mixing than the two way assembly burner. The contours in figure 3b show that the assembly with additional pipe which is more helpful for better pre combustion mixing which results in efficient combustion. The additional air produces turbulence and wake, this additional air is also to re burn the solid particles like coal/biomass in the burner. The graph in figure 4 shows the mean axial velocity variation with respect to characteristic length for different assemblies; it can be seen that the axial velocity decreases with characteristic length. Three way assembly, and two ways assembly has been compared with the results from simulations done on Apte and Mahesh [8] and experimental

work (Somerfield and Qiu, 1991). In figure 4 the mean axial velocity for three way assembly agree well with data. Comparison of radial and swirl velocity has also been done with reference data experimental (Somerfield and Qiu, 1991) from Apte and Mahesh [8]. The swirl velocity decreases with characteristic length this can be seen in above graphs. The radial velocity graph show the different flow property than the swirling and axial velocity here the radial velocity has the increased value at $X/R=0.781$ than the initial point $X/R=0.094$, slightly increases at $X/R=1.6$ and starts to decrease and becomes zero at the end point. The increasing and decreasing radial velocity produce mixing in the combustor. The Pressure is also a property of moving fluid depending on the axial velocity, mathematically it can be written as $P_d = \frac{1}{2} \rho v^2$ it decreases and increases with axial velocity

Where

P_d = dynamic pressure

ρ = density and v = axial velocity

[2]

It is the pressure created in a fluid due to the kinetic energy or it totally depends upon the kinetic energy of the fluid. The variation in dynamic pressure produces wake and is better for mixing phenomena inside the furnace.

CONCLUSIONS

The physics of flow has been analysed to see the pre combustion mixing behaviour of air in two different geometries; the aim of the research is to design a better burner/furnace assembly for solid fuel biomass-coal co firing. The additional unswirled pipe as secondary pipe increases the performance of a biomass coal co fired burner because the solid fuel needs additional air for re burning. The swirling flow produces turbulence, secondary pipe maintains the swirling for most of the time, it can produce wake in axial and radial directions. The efficient co fired burner results in better use of the biomass as main renewable energy source it will result in reduction of SO_x, NO_x, CO and carbon dioxide from the emissions of coal fired power plants. Swirling and dynamic pressure are mostly depend upon the axial velocity or kinetic energy of the fluid. The of radial velocity variations are necessary for mixing

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